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DRAINAGE OF THE KANSAS ICE-SHEET.

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OUR subject has been so shortened for convenience that it is too broad for the intended scope of our paper. We have not time to consider the drainage of the whole ice-sheet of the Kansan epoch in the United States, but only that of its western side, and particularly that in the state of Kansas. It is scarcely necessary to state that it was in the Kansan epoch of the ice age that the great ice-sheet reached its maximum extent; that in the Iowan, which has not been satisfactorily traced in the Missouri valley, the ice did not extend as far by 150 to 200 miles in this direction.

PROBABLE MARGIN OF THE ICE AT THAT TIME.

Some have conceived that the center from which the ice deployed at that time was a point west of Hudson's Bay, called the Kewatin. They have assumed that the ice which entered Kansas came down the James and Missouri river valleys through Dakota and Nebraska. Such a conclusion, however, seems forbidden by the following facts:

1. It would have been impossible for such a long, slender lobe to have maintained itself for 500 miles, with one side exposed for that distance to the heat and warm winds of the western plains. Moreover, the height of the ice in Dakota, necessary to give head sufficient for such a course, must have been attended with a much greater western movement in that latitude than is indicated by any trace yet discovered.

2. Northeastern Kansas would have been more accessible to a Canadian ice-sheet through the Des Moines valley rather than through the Dakota. The distance is shorter, and preglacial surfaces rise 1500 to 1700 feet above sea in northeastern Nebraska. Besides, no clear trace of Kansan drift has yet been found in Dakota.

If it be objected that the divide between the Des Moines and the Missouri is too high, particularly when southeastern Iowa is so much lower, it may be replied that 200 to 350 feet of the divide is glacial till, and that the older surface is not over 1000 feet altitude, and in the northern part, where the more easily eroded Cretaceous rocks are found, cases are reported of preglacial surfaces less than 800 feet above sea. Moreover, there are other reasons for believing the east was relatively higher at that time.

3. Glacial striæ in eastern Nebraska and northeastern Kansas indicate that the main movement in those regions was from the northeast. Those which indicate other movements are low down in valleys and correspond to a thin and wasted stage of the ice. Some recorded are the following: Omaha, S. 41° W.; Bennet, S. 17°, 41°, 43°, 61° and 88° W.; Weeping Water, larger grooves, S. 29° W.: St. Joseph, Mo., 125 feet above Missouri river, S. and S. 26° W.; near Seneca, Kan., S. 21°-24° W.

A collection of more characteristic boulders sent to Minnesota geologists were found to agree, most of them, with ledges found within the borders of that state. Perhaps 90 per cent. of the boulders in Kansas are varieties of red quartzite from the Algonkian of southern Minnesota and South Dakota. Nebraska geologists have usually referred similar ones in their state to Dakota, but a striking feature of many of them is the abundance of white quartz pebbles in them. Such rock is found in ledges in Cottonwood and Rock counties in southwestern Minnesota, but is not prominent, if found at all, in South Dakota. This is very likely due to the former being nearer the parent granitic rocks which furnish the framental material.

Again, if the quartzite came from Dakota it would naturally have been on the east side of the Dakota lobe and not on the extreme western margin of the drift, as we find the boulders in Kansas. On the other hand, if from Minnesota the observed distribution would follow.

We conclude, therefore, that the western limit of the ice during the Kansan was probably not west of the Coteau des Prairies in eastern Dakota, thence south-southwest across Nebraska, a little west of Fremont and Lincoln, Neb., and east of the Big Blue into Kansas and south in that state to the Kansas river, perhaps, near Topeka, but probably not to that stream further east until near the Missouri, reaching the vicinity of Kansas City.

THE LINE OF THE MASTER DRAINAGE STREAM.

Probably the James river approximately marks the course of that ancient stream through the Dakotas, the Big Sioux joining it near Vermilion, S. Dak. Its level was doubtless relatively higher than now, for the erosion of the Cretaceous clays, which cover that region, by the Iowan and Wisconsin ice-sheets was no doubt great.

Through Nebraska its course was perhaps south-southwest to the Elkhorn near Westpoint, which stream it may have followed always, thence we may suppose across over the present low valley of the Platte and across lower places in the hills south past Valparaiso to Milford on the Big Blue, which it followed approximately to the Kansas and the Kansas to the Missouri.

This may have been the line when the ice was at the maximum; but later lines, which may have been occupied longer when the ice was pausing in its retreat, may be followed now by Logan creek to the Elkhorn, by ancient valley along Sand creek and Wahoo creek in Saunders county, by Salt creek, and over to the Big Blue, near Crete. It is conceivable also that a lake basin may have occupied portions of the route at different times, particularly between the Elkhorn and Blue.

After reaching the Blue the route is comparatively clear. It followed down the course of that stream with an overflow, either in earlier stage or in time of flood, across to the Little Blue at Fairbury, Neb., and then down that stream back to the main stream. From the mouth of that stream it followed approximately the course of the Kansas river to the Missouri, at Kansas City. We say approximately, for the stream was at first about 200 feet higher than the present stream and there are numerous cases where channels crossed the present divides between that stream and its southern tributaries, for a distance of ten to fifteen miles in places, from the present Kansas.

Through Nebraska, stream deposits have not been traced over much of the distance, doubtless partly because diligent search has not yet been made. Along the Blue and Kansas they are frequently found at different levels. The most characteristic deposits of the higher terraces and channels are strips of boulders mingled with gravel and clay. The boulders are of local limestone mingled with crystalline rocks from the north, particularly the red quartzite before mentioned.

The highest level of drift terraces is about 1000 feet above sea, at a point southwest of Lawrence; 1050 to 1100 southwest of Topeka, and about 1200 south of Wabaunsee. At Fairbury, Neb., gravel occurs about 1325. To pass over the divide between the Blue and Salt creek an altitude of about 1425 is necessary at Berks, and higher farther north. Probably somewhat greater altitude would surmount the divide between the basin of Salt creek and Platte river near the northwest corner of Sanders county. Northwest of Westpoint, Neb., stratified deposits containing drift occur at less than 1450, but, as suggested before, the line may have followed up Logan creek. To pass the divide from that stream to the Missouri and mouth of James river would have required 1650 at least; and to reach the Missouri by way of Aoway creek, probably 1500 feet.

This would imply a stream 275 to 300 feet higher than the present James river, occupying at that time the valley of that stream, which would seem an insurmountable objection to our conception. There are three things which reduce the difficulty. First, by noting that the Wisconsin ice-sheet may have removed 150 to 200 feet depth from the bottom of the valley. There seems to be some evidence of this when we find bed-rock considerably over 100 feet higher on the south of the Missouri at Yankton and Vermilion. S. Dak., than on the north side of the same. Secondly, there may have been more or less of lacustrine conditions between the Missouri and Big Blue rivers in northeastern Nebraska. This agrees with the lack of coarse stratified deposits in that region, so far as is yet known. Yet the pebbly clay shows unusual stratified features near Westpoint and west of Fremont. Thirdly, the more recent elevation of central Kansas, or the depression of areas toward the northeast, in Iowa and Wisconsin.

At Blaine, Pottawatomie county, Kansas, nearly at the extreme advance of the ice in that state, clear evidence is shown that localities over 1500 feet above sea-level were swept over by the ice-sheet. This is nearly twice the altitude of central Iowa. How then could the ice have taken such a westerly trend, with lower or equal plains southeast, in southeastern Iowa and Illinois, unless there had been an appreciably western or southwestern slope of the preglacial surface ? Such a condition would have rendered the drainage line suggested considerably more rational. As we have found it the slope seems much too steep eastward down the Kansas and too flat or sluggish from the Missouri to the Blue.

A speculation easily following from this conception is that not long before the glacial advent, possibly the difference in slope of the surface may have been enough to have reversed the flow in the valley of the Kansas and it may have flowed via Salina and McPherson through the buried channel at the latter place into the Arkansas river. The accumulation of the ice on the northeast may have reduced the slope of the stream so that it aggraded rapidly, so that the McPherson channel was filled, and when the great stream draining the west edge of the ice-sheet arrived, the surface in time was tilted so that the drainage was eastward around the edge of the ice, as we have seen.

PLEISTOCENE AND MORE RECENT EROSION.

Doubtless to some a great objection to our view will be found in the amount of erosion which it assumes. It really infers that the main valley of the Kansas river was three to four miles wide and

200 feet deep, at least that below Manhattan, and those of its tributaries have been excavated since the ice first reached its maximum limit.

It has been assumed by some that this main valley was preglacial, because large northern erratics are now found in its bottom and under heavy alluvium; but a moment's thought will show that it would not be otherwise if these boulder deposits had been let down by undermining, from terrace to terrace, in erosion which was subsequent to the advent of the ice. Perhaps the idea was at first received because these boulders were so deeply covered with alluvium. Not long ago it was thought that the recent alluvium of a stream could not exceed 20 or 25 feet, but now it is known that it may exceed 100 feet. (See Bulletin 158, U. S. Geol. Survey, p. 150.)

That the general surface of the region and level of drainage was high at that time is indicated in several ways: (1) Glacial deposits are limited to higher levels. About Kansas City glacial striæ have not been found lower than about 125 feet above the Missouri river, or 850 A. T. (2) The till in Kansas lies on the divides but has not been found in the valleys. (3) At Weston, Mo., a cobble-stone stratum, about 20 feet thick, lies upon Carboniferous shales about 150 feet above the Missouri. It contains red quartzite and granite boulders, mingled with many of limestone. It seems therefore to show that the river was flowing at that level when glacial erratics entered the region. As already stated, the earliest bouldery strips beyond the edge of the till in Kansas were at high levels. We may imagine the shallow pioneer streams around the front of the ice, as assisted by floe-ice and anchor-ice.

The erosion of valleys 200 feet deep, and mainly during the Kansan epoch, may seem too much for the credulty of some, but there are several considerations which may make it more plausible.

1. The probable volume of the stream. The whole western slope of the great ice-sheet of that time probably included half of the Dakotas, much of Minnesota, Iowa, Nebraska, Kansas and Missouri. Omitting the last as not affecting our problem, but remembering that probably as much in Canada as that enumerated which would drain this way, we may reasonably count the ice-surface contributing as over 200,000 square miles. The amount of ablation or melting of Alpine glaciers has been estimated by DeSor as ten feet a year; by Forbes as twenty feet, and even two and one-half inches a day have been reported. Taking five feet as a conservative average, we should have a little less than 100 cubic miles

a year. The Missouri is estimated to discharge an annual average of 24.41 cubic miles. Let the drainage from the west be counted as somewhat more than at present, because of a moister climate then, and we can readily believe that the Kansas of that time may have averaged five times the present Missouri, with possibly ten times in unusual years.

2. The country rock of the region is mainly shale and shaly sandstone. The limestone comprises less than one-tenth and is in comparatively thin layers and small blocks. Such an arrangement affords conditions very favorable for rapid erosion.

3. It was probably a time of greater variation of volume in streams and also of frequent freezing and thawing. Both tended to increase the erosion.

What corrasion such a stream would accomplish can scarcely be conceived, but it may be believed to have been fully adequate to the work supposed.

Again, the length of time during which this line of drainage was occupied was long. Students of glacial deposits tell us that since the culmination of the Kansan ice the time has been from 330,000 to 1,000,000 years. A meager 1000 years might be allowed for the life of the great stream which we have sketched, and, from considerations we have entertained, it would seem much less time might be sufficient to excavate the valleys as we now find them. The chief delay was doubtless the cutting down of the heavy limestones which lie athwart the course of the Missouri river in eastern Missouri.

This discussion is but a preliminary sketch of the problems involved in Kansas Pleistocene geology. Our inferences are tentative only. Careful study may modify them in unexpected ways, yet we believe we are on the right track in several particulars. The coöperation of all interested in the subject is hopefully solicited.